Intelligent Compaction

Introduction

- Dave Peterson peterson_david_n@cat.com
- Cat Paving Products, Maple Grove, MN
- Worldwide markets
  - North America, South America, Europe, Asia, Africa/Middle East, Russia
- Asphalt pavers, cold planers, rotary mixers, compactors

What is Intelligent Compaction?

"Intelligent Compaction (IC) refers to the compaction of road materials, such as soils, aggregate bases, or asphalt pavement materials, using modern vibratory rollers equipped with an integrated measurement system, an onboard computer reporting system, Global Positioning System (GPS) based mapping, and optional feedback control. IC rollers facilitate real-time compaction monitoring and timely adjustments to the compaction process by integrating measurement, documentation, and control systems. IC rollers also maintain a continuous record of color-coded plots, allowing the user to view plots of the precise location of the roller, the number of roller passes, and material stiffness measurements."

http://www.intelligentcompaction.com

Primary components of IC:

1. Positioning (GNSS)
   - GNSS – Global Navigation Satellite System
   - SBAS, UTS, VRS
2. Compaction measurement values
   - CMV – Compaction Meter Value
   - MDP – Machine Drive Power
3. Color-coded video display of "real-time" information
4. Data management – VisionLink™ software
   - Storing & analyzing data

Soil Compactor

Caterpillar offered

SITECH offered

- Send data to cloud - VisionLink
- Multiple machine data sharing

SNM940 - and -

SNRxxx

MS952 or

MT900

CB460

3rd Party Printer

Intelligent Compaction
MDP System
Caterpillar Exclusive

Intelligent Compaction
CMV System

Operator's view

Operator's view

Conventional measurement


Less than 1%
With the traditional compaction measurement, what percentage of the surface is actually measured?

What are the benefits of IC?

Quality Control & Efficiency

- Increased operator awareness
  - Real-time pass count & CMV information
  - Real-time identification of soft spots
- More uniform density
- More efficient pass coverage
- Documentation of 100% of the job
- Finding soft areas
- Increased level of confidence that density specifications have been met (before nuclear gauge tests are taken)

Positioning (GPS) Accuracy

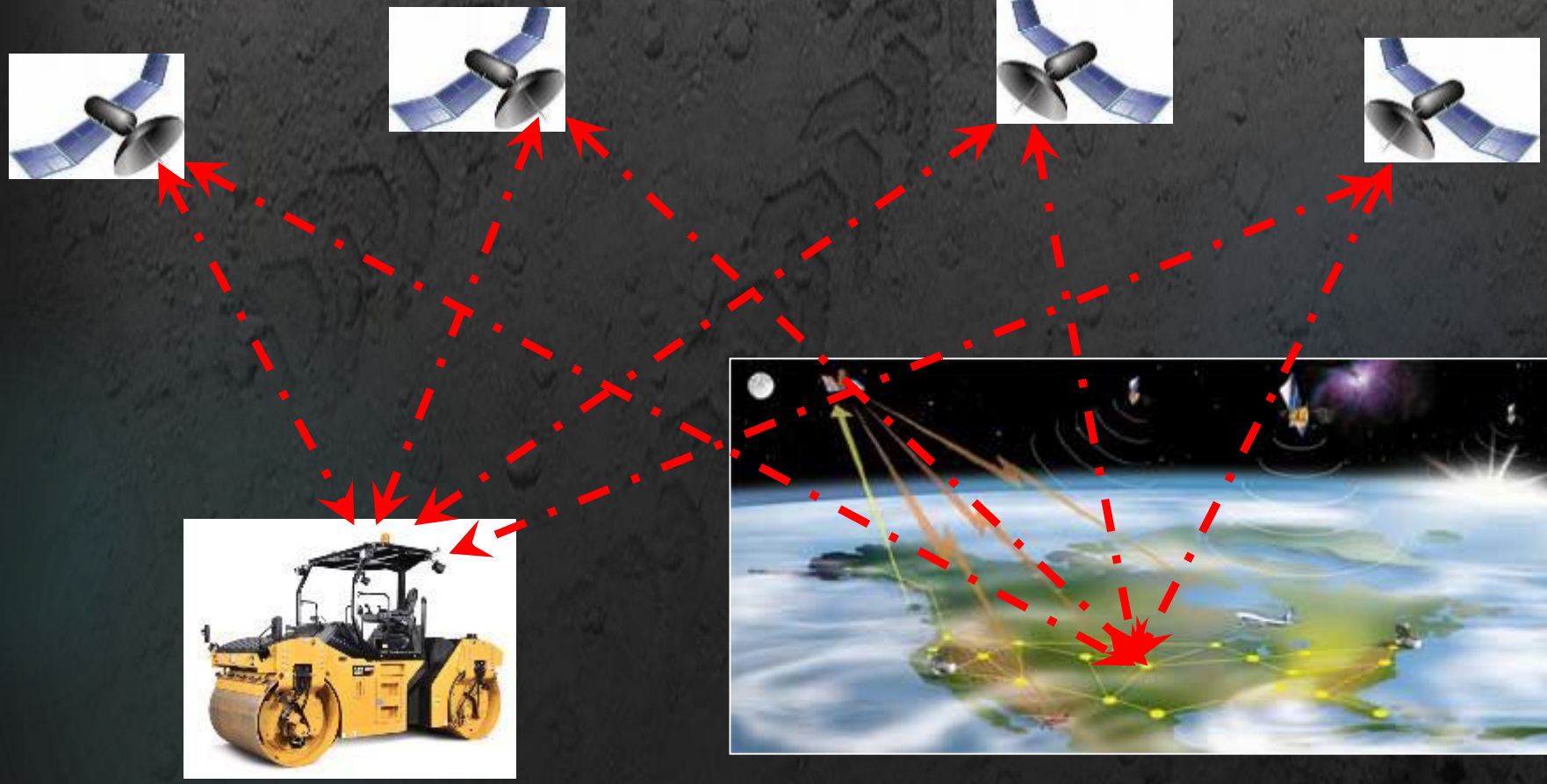
Autonomous: 10 – 30 ft

RTK: < 1”

Autonomous: 10 to 30 feet

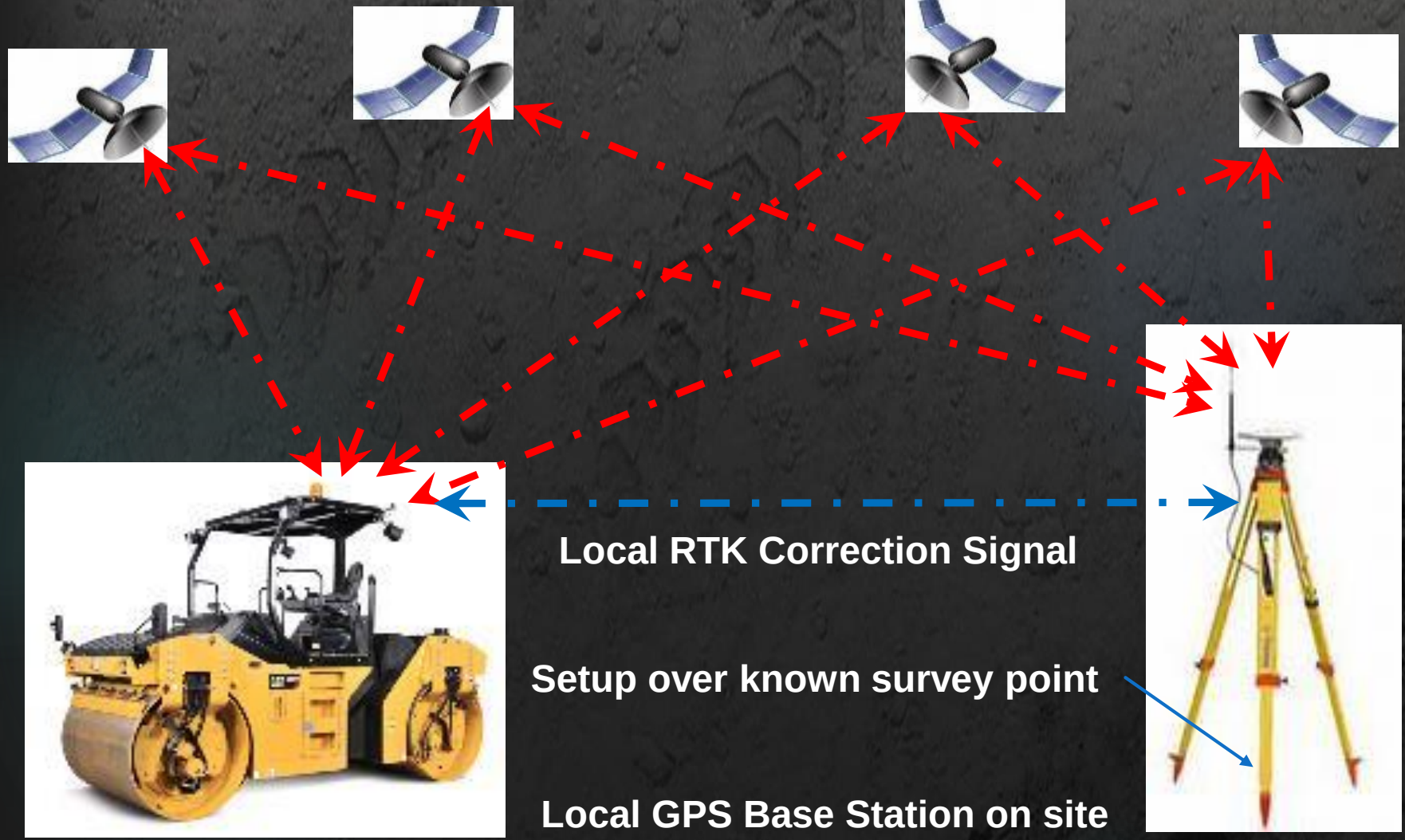
- Direct from satellites
- “floats” from day-to-day
- Simple, inexpensive, no cost

Satellite Based Augmentation System: 3-10 ft



- SBAS is a form of "Differential GPS" (DGPS)
- Receives corrections from nearest fixed, ground-based GPS correction stations

RTK (Real-Time Kinematic): < 1”



Local RTK Correction Signal

Setup over known survey point

Local GPS Base Station on site

Cat Compaction Control

- Compaction Meter Value (CMV) – accelerometer
- Machine Drive Power (MDP) – energy-based system

Two Technologies

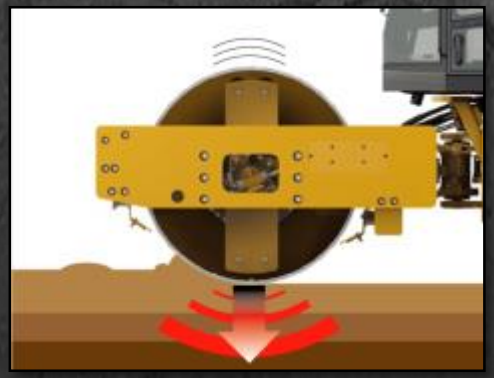
– Compaction Meter Value (CMV) only

– Machine Drive Power (MDP) only

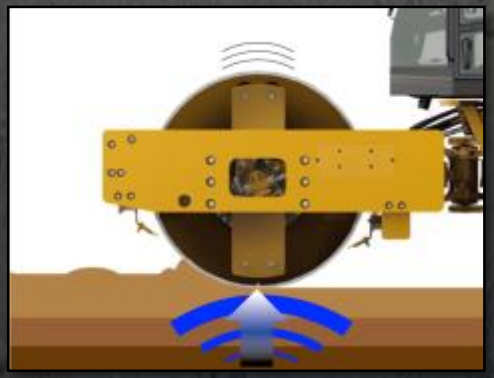
– Both CMV and MDP

CMV measurement vs MDP measurement

CMV



Vibrating drum strikes the soil.



Accelerometer senses the soil reaction and converts to a CMV value.

MDP

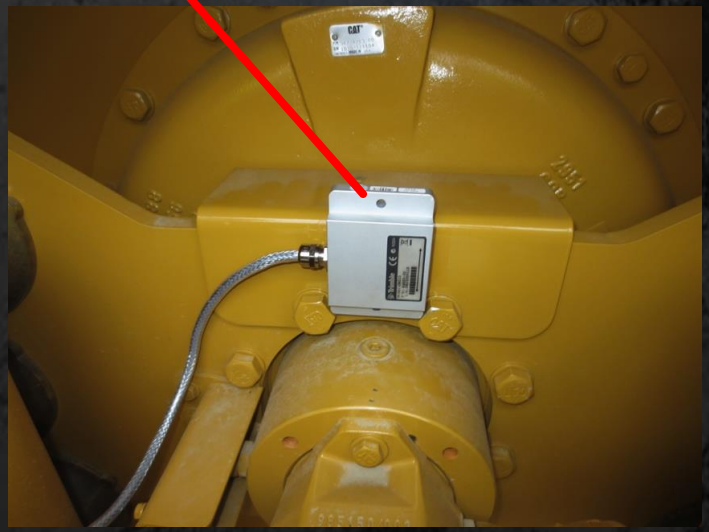
It takes little effort to push a wheelbarrow on stiff surfaces like concrete.

It takes much more effort to push the wheelbarrow through loose soil– in essence, MDP measures this effort by the soil compactor. The more compact the ground, the less energy is required to propel.

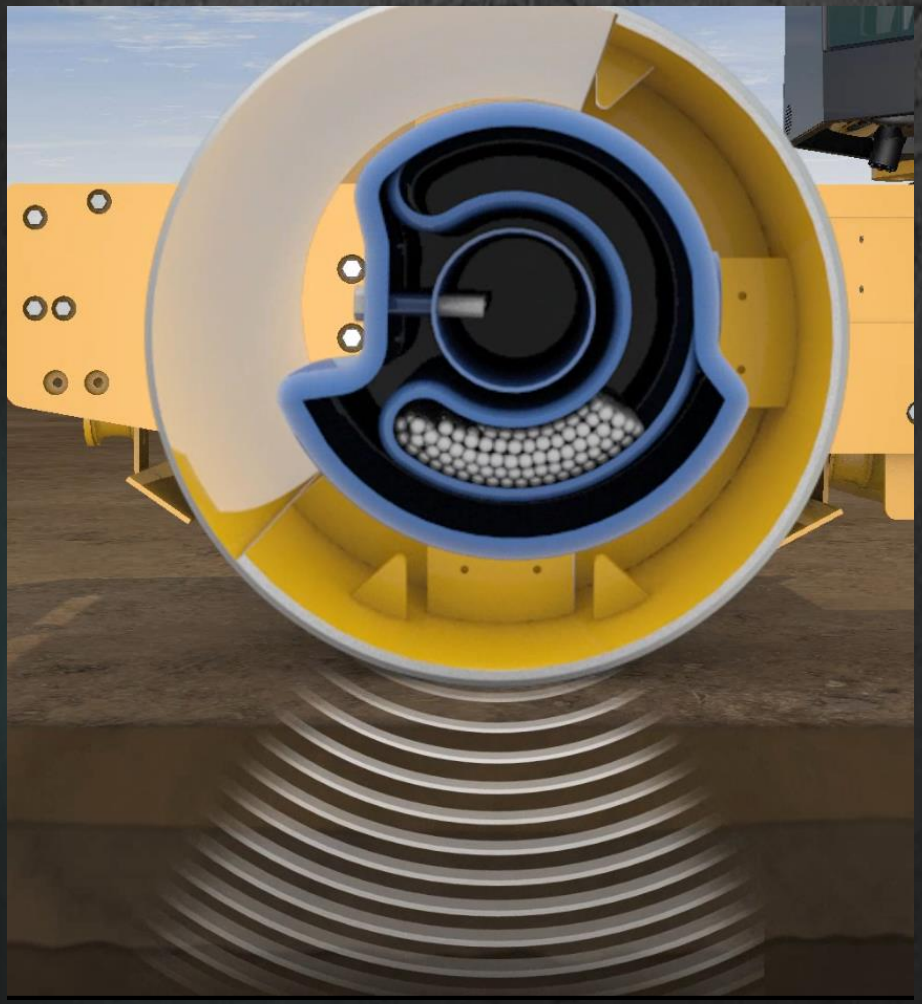
Compaction Meter Value (CMV)

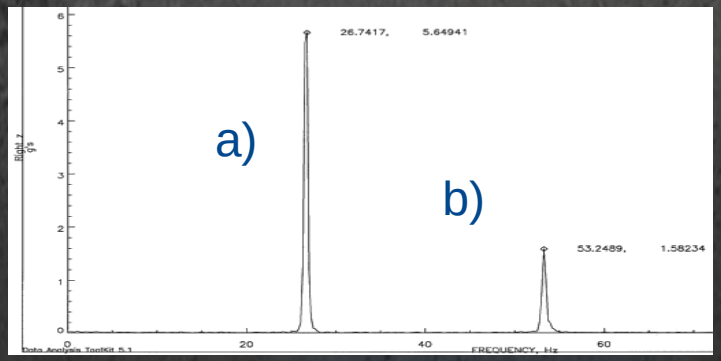
- Accelerometer-based
  - Widely available all OEMs
  - Recommended use on granular soils
  - Measures up to 6 feet below surface
  - Vibratory system must be activated

- Benefits of technology:
  - Measures a large volume
  - Reveals “soft spots” tree trunks, tires, clay balls, etc.
  - Indicator of load-bearing capacity



Accelerometer



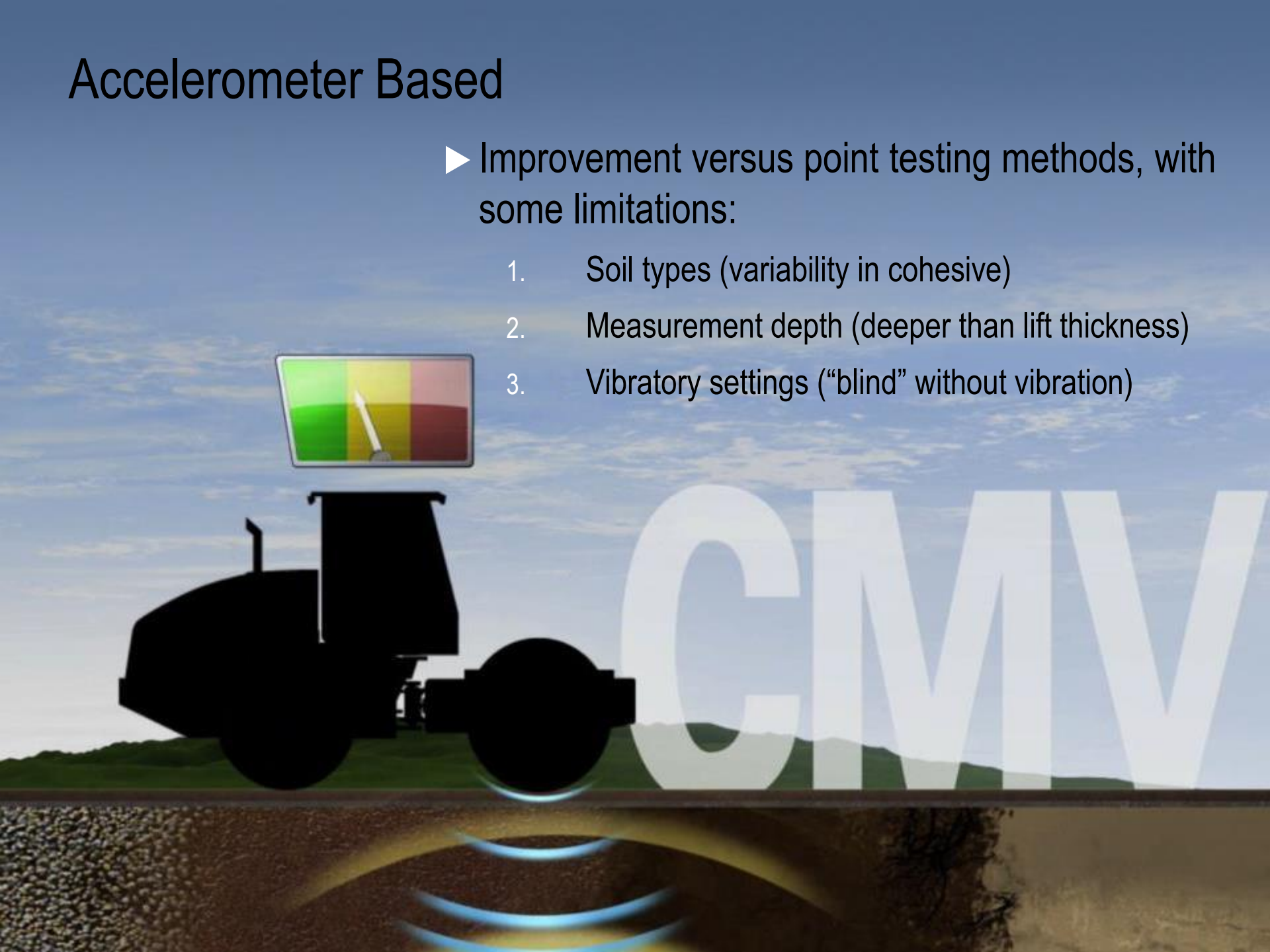


a) Fundamental Frequency
b) 2nd Harmonic Frequency

Soil Stiffness indicated as a ratio of b:a

Accelerometer Based

- Improvement versus point testing methods, with some limitations:
  1. Soil types (variability in cohesive)
  2. Measurement depth (deeper than lift thickness)
  3. Vibratory settings (“blind” without vibration)



MDP measures what matters – closer to the depth of the material layer you are compacting.

Things to understand about CMV…

- CMV values are influenced by sub-surface conditions up to 6’ depth.
- CMV is an indicator of soil stiffness, NOT a measure of density.
- Many factors influence CMV value such as machine speed, direction, amplitude setting, frequency setting, machine weight, etc.
- Correlations between CMV and conventional measurement methods is difficult to achieve.
- CMV values are not comparable between machines.

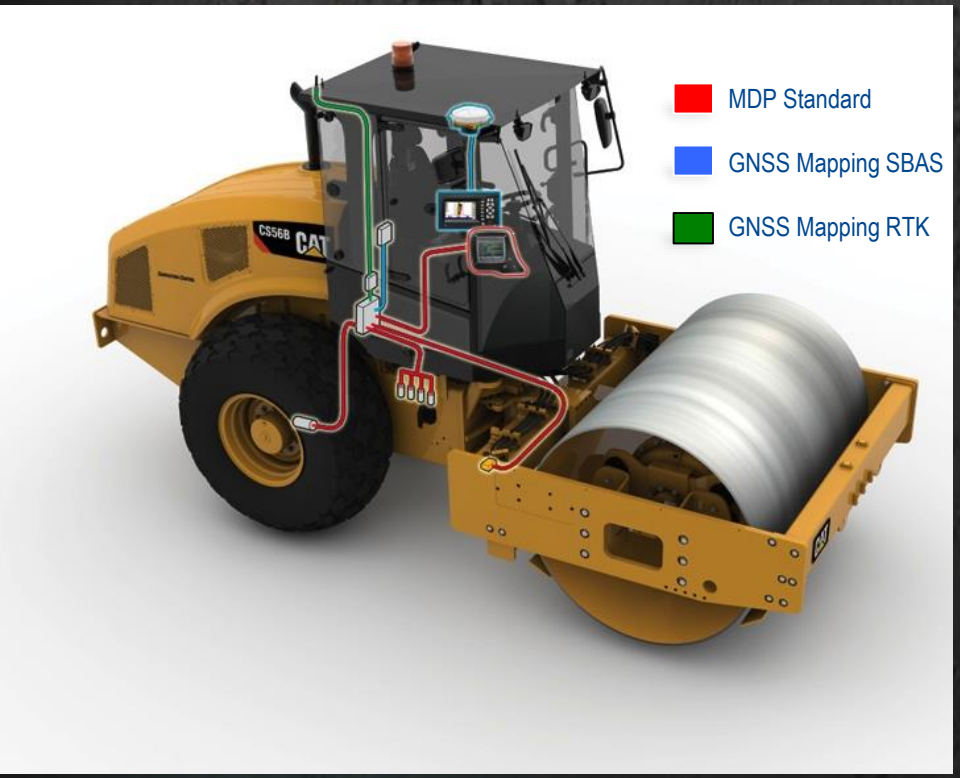
Machine Drive Power

- Is an integrated system in the hydrostat transmission that measures the energy required to overcome rolling resistance…

Soft ground = hard to push

Hard ground = easy to push

Machine Drive Power (MDP)

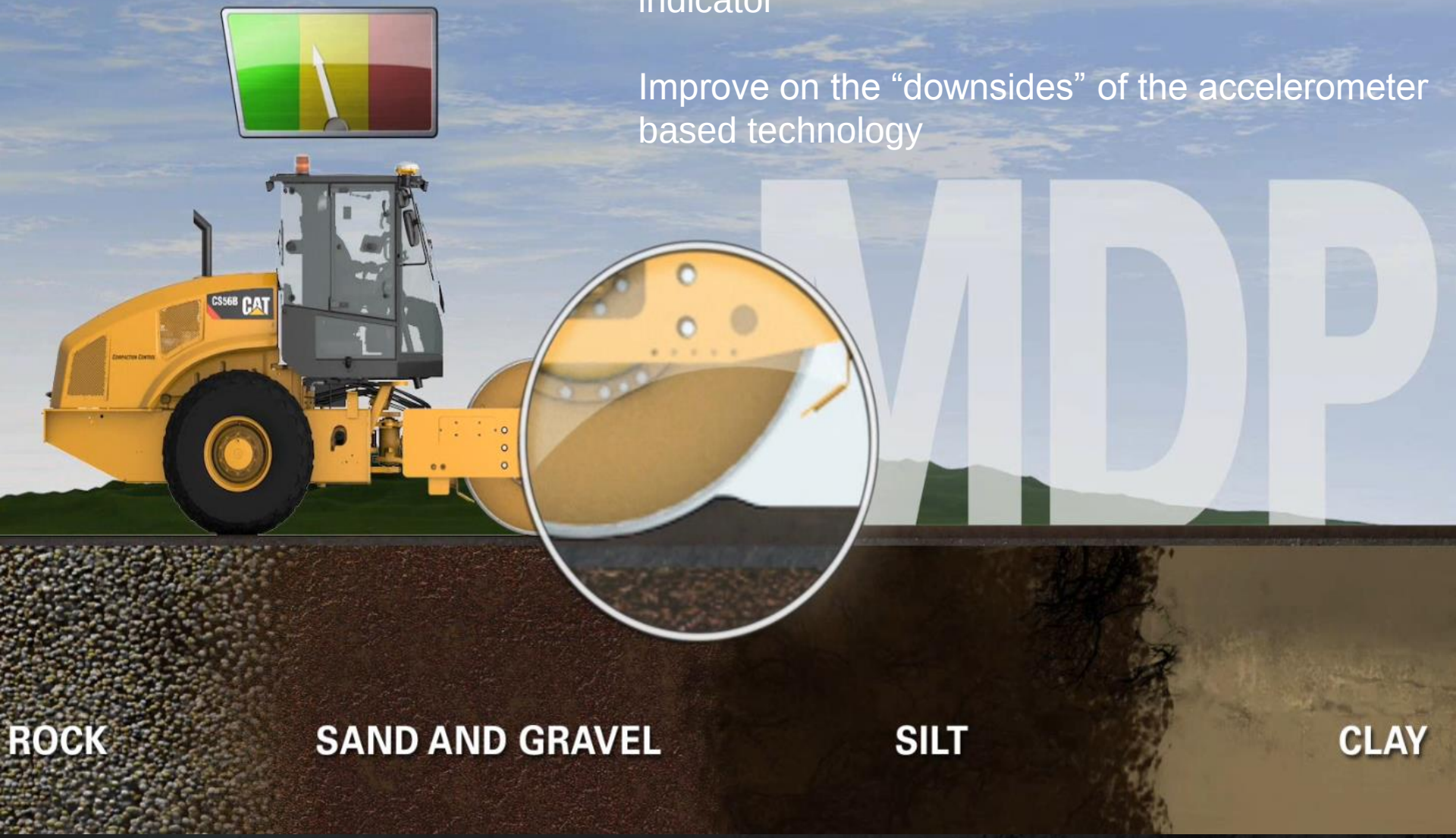


- Energy-based
  - Measures rolling resistance
  - Good results on both smooth drum and padfoot rollers
  - Works on granular and cohesive soils
  - Works with vibe system on or off
  - Measures 30-60 cm (1 – 2 ft) deep
- Benefits of technology:
  - Measures closer to the depth of the lift you are working
  - Applicable to a wide range of soil types
  - Correlates well with portable measurement devices

Energy Based

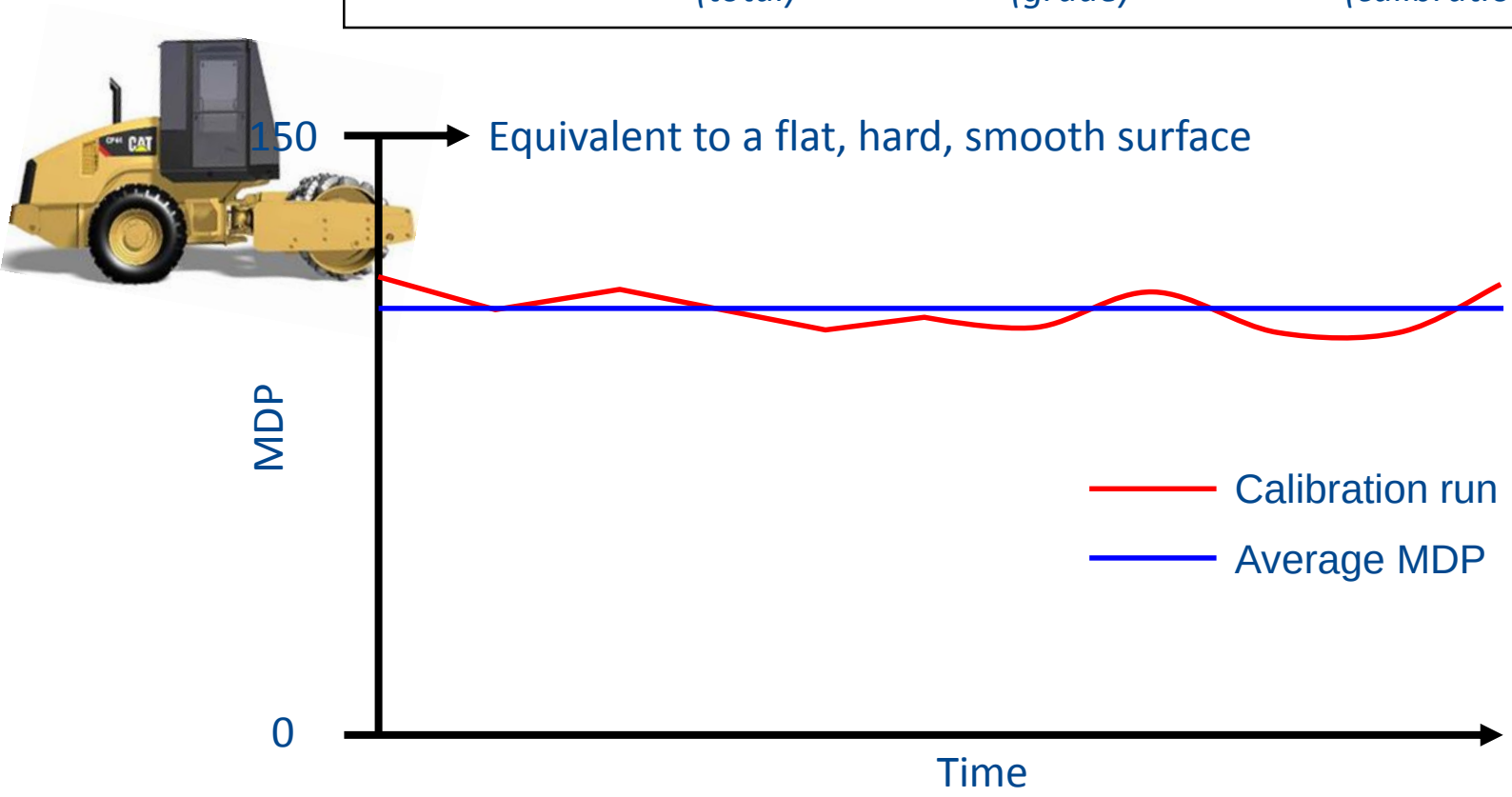
Relate to the physical properties of the material being compacted, using machine energy as an indicator

Improve on the “downsides” of the accelerometer based technology



Calculation: MDP

$$MDP = Power_{(total)} - Power_{(grade)} - Power_{(calibration)}$$

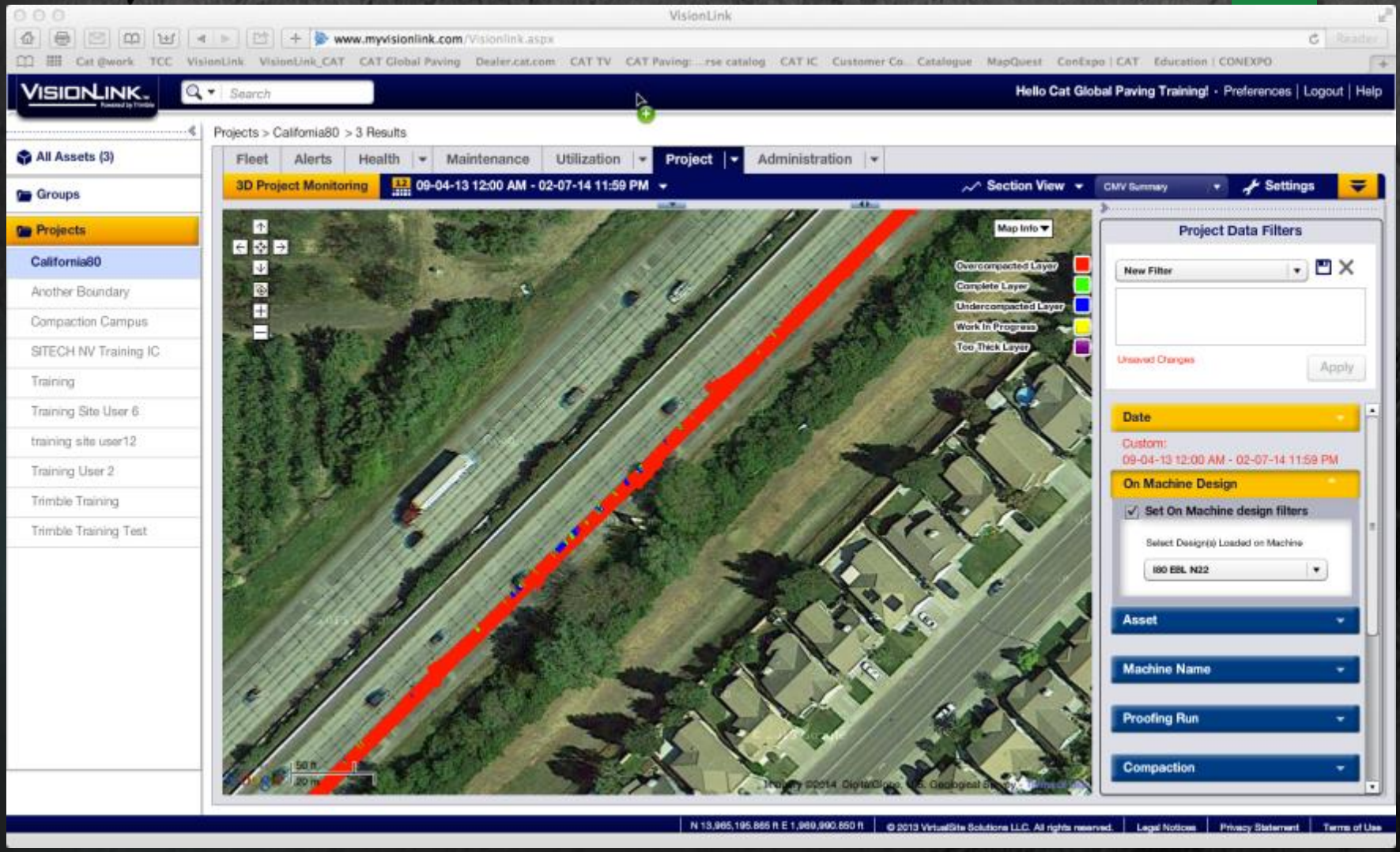


Comparing MDP to CMV

	Machine Drive Power	Compaction Meter Value
Measurement basis	Rolling resistance / Energy	Accelerometer
Vibe system for measurement	Active or inactive	Active only
Soil types	Granular or Cohesive	Granular only
Machine configuration	Smooth drum, Padfoot, Shell kit	Smooth drum only
Measurement depth*	30 – 60 cm (1-2 feet)	1- 2 meters (3 - 6 feet)
Can add GNSS mapping	Yes	Yes
Availability	CAT Dealers only	Several manufacturers including CAT

**Depends on machine weight and soil type / conditions.*

CMV on I-80: Asphalt over PCC slabs



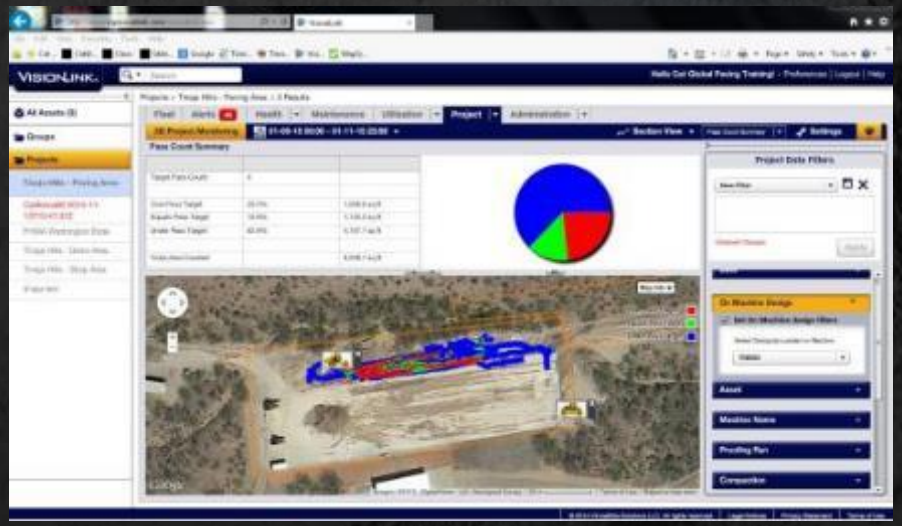
GPS locates soft spots with CMV

Pre-mapping to find soft areas before paving

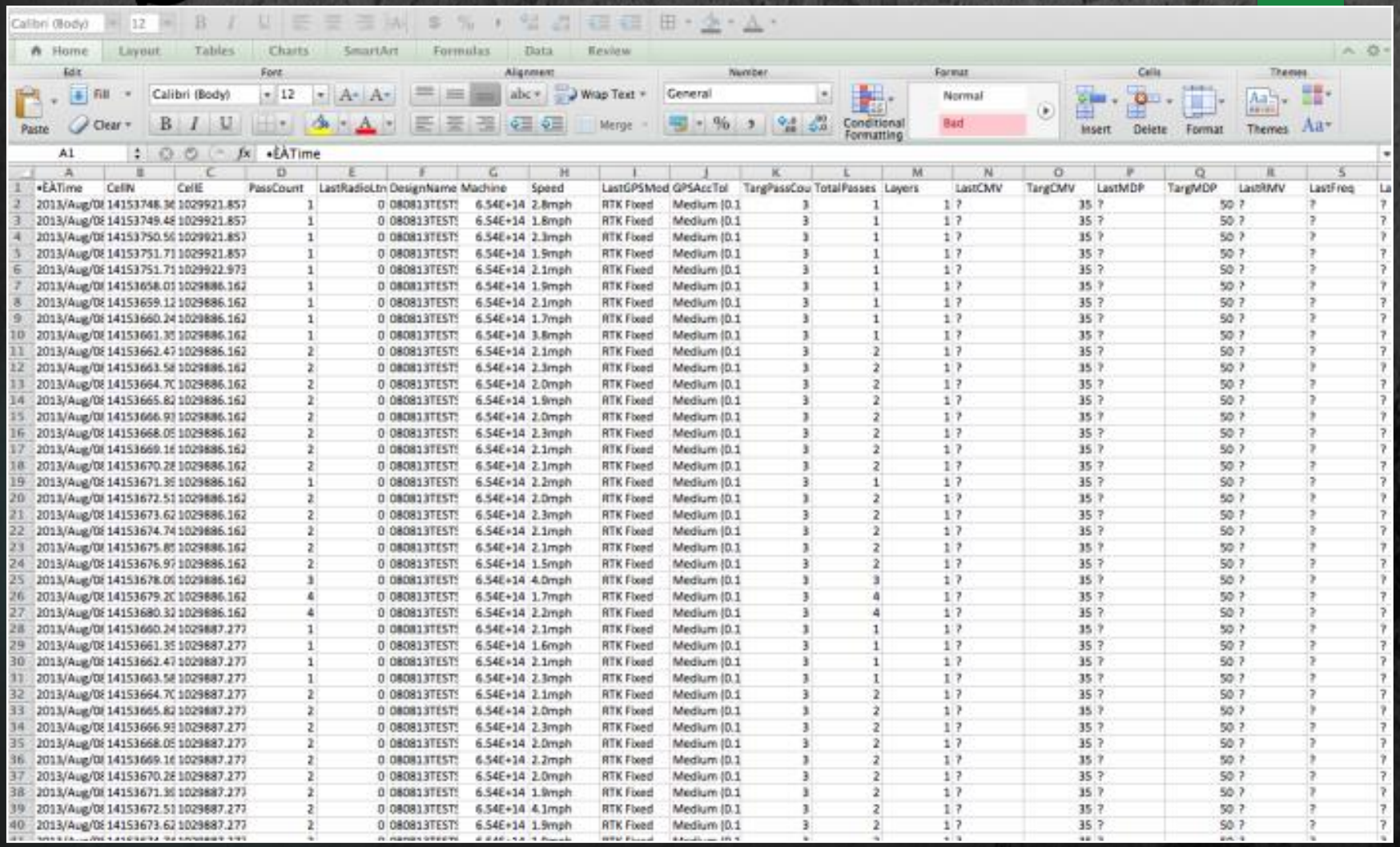
Data Collection & Management

- Data collection
  - Stored on CB460 display
  - Manual via USB drive
  - Wireless data transfer

- VisionLink software
  - Needed to view IC data
  - Web-based software
  - Can export IC data into MS Excel
  - Purchased from Sitech
  - Monthly fee

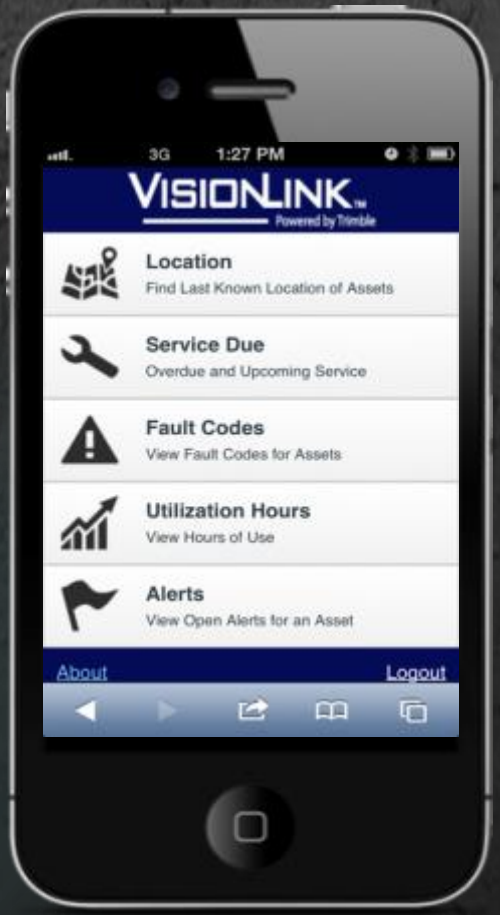


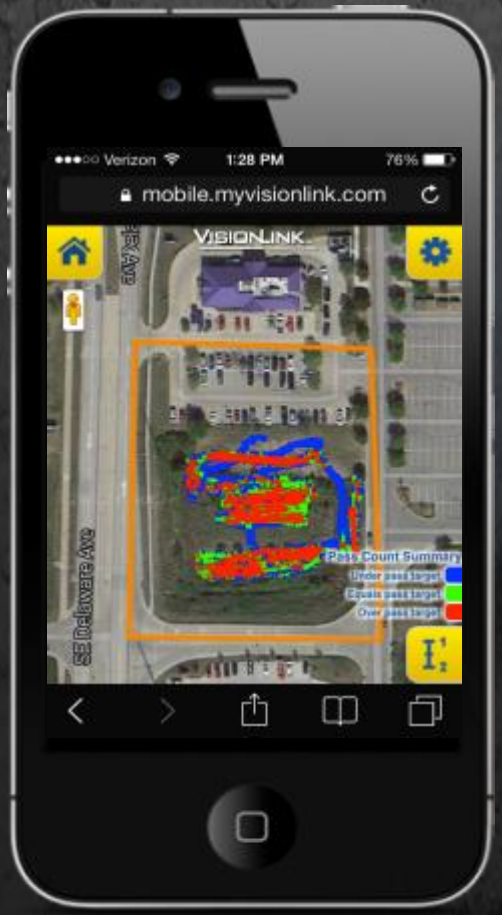
Data can be exported in *.csv (MS Excel) format



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	•ÈÀTime	CellN	CellE	PassCount	LastRadioLtn	DesignName	Machine	Speed	LastGPSMod	GPSAccTol	TargPassCou	TotalPasses	Layers	LastCMV	TargCMV	LastMDP	TargMDP	LastRMV	LastFreq
2	2013/Aug/08	14153748.36	1029921.857	1	0	080813TEST!	6.54E+14	2.8mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
3	2013/Aug/08	14153749.48	1029921.857	1	0	080813TEST!	6.54E+14	1.8mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
4	2013/Aug/08	14153750.56	1029921.857	1	0	080813TEST!	6.54E+14	2.3mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
5	2013/Aug/08	14153751.71	1029921.857	1	0	080813TEST!	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
6	2013/Aug/08	14153751.71	1029922.973	1	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
7	2013/Aug/08	14153658.03	1029886.162	1	0	080813TEST!	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
8	2013/Aug/08	14153659.12	1029886.162	1	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
9	2013/Aug/08	14153660.24	1029886.162	1	0	080813TEST!	6.54E+14	1.7mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
10	2013/Aug/08	14153661.35	1029886.162	1	0	080813TEST!	6.54E+14	3.8mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
11	2013/Aug/08	14153662.47	1029886.162	2	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
12	2013/Aug/08	14153663.58	1029886.162	2	0	080813TEST!	6.54E+14	2.3mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
13	2013/Aug/08	14153664.70	1029886.162	2	0	080813TEST!	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
14	2013/Aug/08	14153665.82	1029886.162	2	0	080813TEST!	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
15	2013/Aug/08	14153666.93	1029886.162	2	0	080813TEST!	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
16	2013/Aug/08	14153668.05	1029886.162	2	0	080813TEST!	6.54E+14	2.3mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
17	2013/Aug/08	14153669.16	1029886.162	2	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
18	2013/Aug/08	14153670.28	1029886.162	2	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
19	2013/Aug/08	14153671.38	1029886.162	1	0	080813TEST!	6.54E+14	2.2mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
20	2013/Aug/08	14153672.51	1029886.162	2	0	080813TEST!	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
21	2013/Aug/08	14153673.62	1029886.162	2	0	080813TEST!	6.54E+14	2.3mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
22	2013/Aug/08	14153674.74	1029886.162	2	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
23	2013/Aug/08	14153675.85	1029886.162	2	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
24	2013/Aug/08	14153676.97	1029886.162	2	0	080813TEST!	6.54E+14	1.5mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
25	2013/Aug/08	14153678.09	1029886.162	3	0	080813TEST!	6.54E+14	4.0mph	RTK Fixed	Medium (0.1	3	3	1	?	35	?	50	?	?
26	2013/Aug/08	14153679.20	1029886.162	4	0	080813TEST!	6.54E+14	1.7mph	RTK Fixed	Medium (0.1	3	4	1	?	35	?	50	?	?
27	2013/Aug/08	14153680.32	1029886.162	4	0	080813TEST!	6.54E+14	2.2mph	RTK Fixed	Medium (0.1	3	4	1	?	35	?	50	?	?
28	2013/Aug/08	14153660.24	1029887.277	1	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
29	2013/Aug/08	14153661.35	1029887.277	1	0	080813TEST!	6.54E+14	1.6mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
30	2013/Aug/08	14153662.47	1029887.277	1	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
31	2013/Aug/08	14153663.58	1029887.277	1	0	080813TEST!	6.54E+14	2.3mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
32	2013/Aug/08	14153664.70	1029887.277	2	0	080813TEST!	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
33	2013/Aug/08	14153665.82	1029887.277	2	0	080813TEST!	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
34	2013/Aug/08	14153666.93	1029887.277	2	0	080813TEST!	6.54E+14	2.3mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
35	2013/Aug/08	14153668.05	1029887.277	2	0	080813TEST!	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
36	2013/Aug/08	14153669.16	1029887.277	2	0	080813TEST!	6.54E+14	2.2mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
37	2013/Aug/08	14153670.28	1029887.277	2	0	080813TEST!	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
38	2013/Aug/08	14153671.38	1029887.277	2	0	080813TEST!	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
39	2013/Aug/08	14153672.51	1029887.277	2	0	080813TEST!	6.54E+14	4.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
40	2013/Aug/08	14153673.62	1029887.277	2	0	080813TEST!	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?

VisionLink Mobile

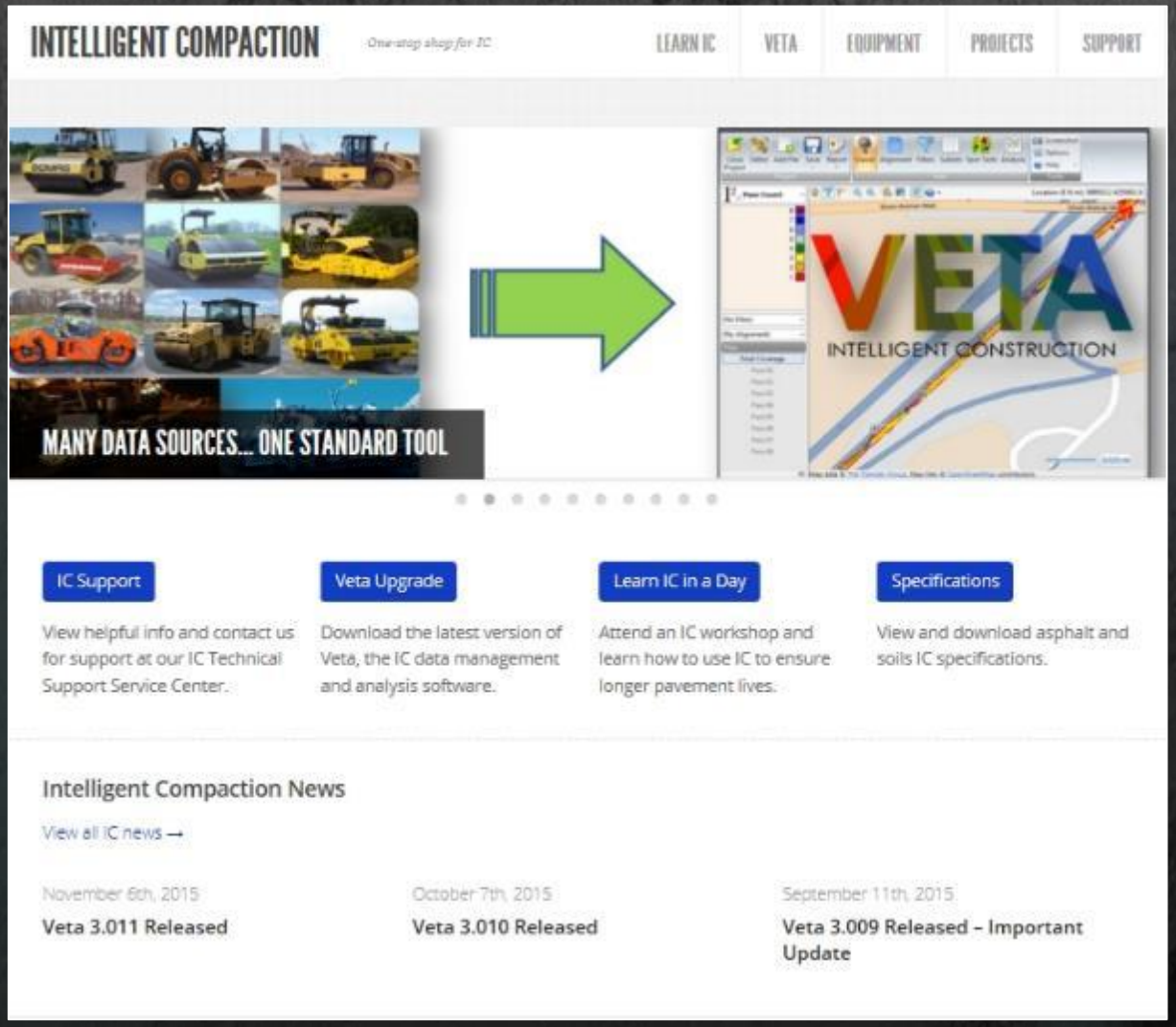




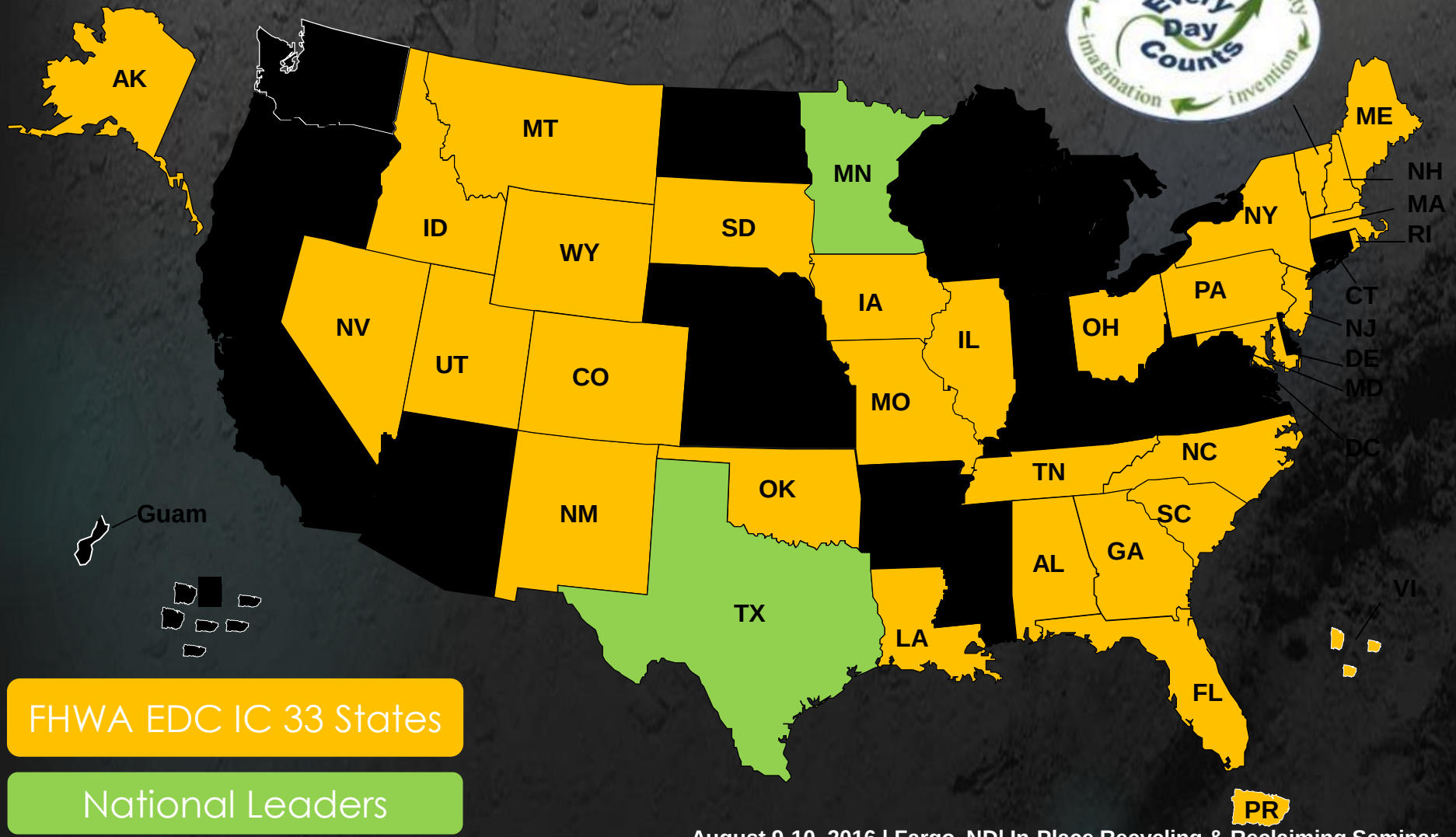
What are the Benefits of IC?

- Quality Control & Process Control
  - Real-time information that is "actionable"
  - Increased Operator Awareness – self training tool
  - Improved Density & Smoothness – uniformity
  - Operator productivity – reduced passes
  - Documentation of 100% of job!!
  - Reduced compaction testing frequency, allowing more efficient allocation of QC people

www.intelligentcompaction.com



EDC IC National Deployment



FHWA EDC IC 33 States

National Leaders

University Research – Iowa, Tennessee

Intelligent Compaction
for Soils, Aggregate and HMA

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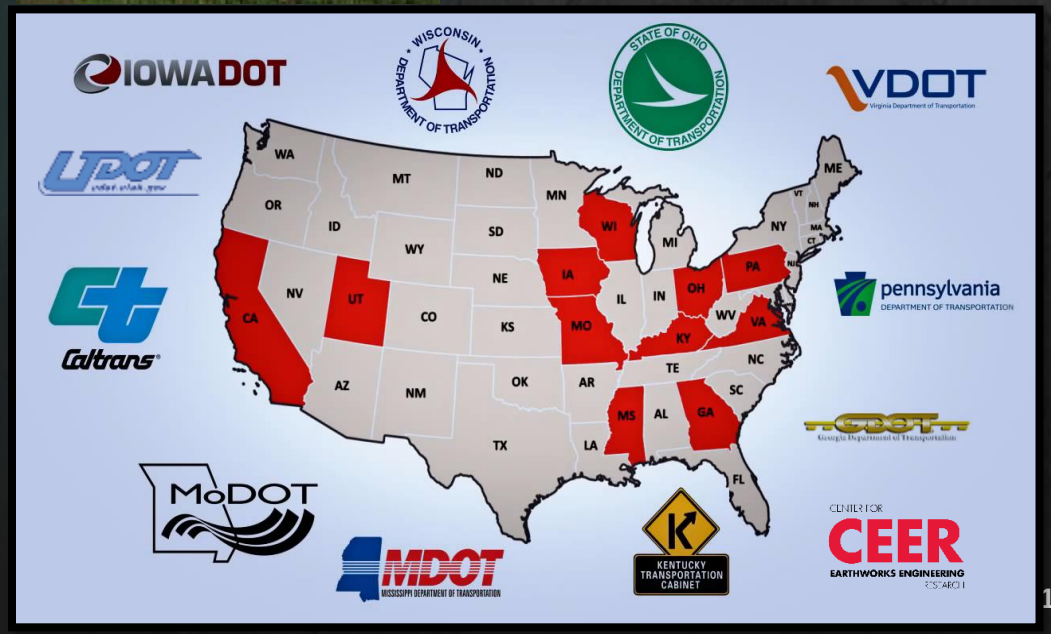
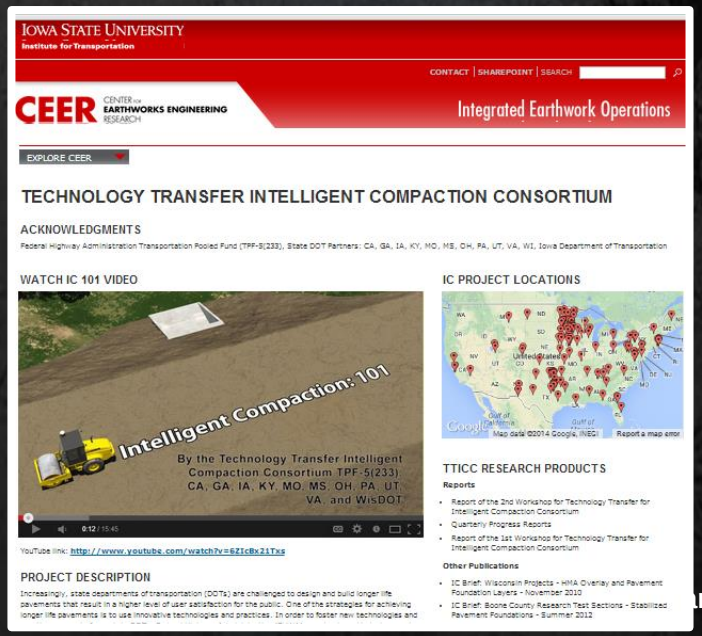




Rubblized PCC I-39 Wisconsin

Airport P-201 base - California

Emulsion stabilized base - MN

Current drawbacks with IC

- Cost of IC is ~ 30% of roller cost, but decreasing
- Obtaining a good correlation of RMV (stiffness) to in-place density
- ROI is very company-dependent
- Manufacturers are keeping technology proprietary to their rollers

Effect of underlying materials continues to be evaluated

Some questions to ask on bids…

1. What accuracy of GPS is required?
2. What happens if/when GPS signal is lost?
3. What is the expectation for data transfer? Daily? Wireless? USB? Printout?
4. What data collection/processing software is required?
5. Does it need to be VETA-compatible?
6. Is training required? By the Dealer? OEM?
7. Is a "Work Plan" required by the Contractor?
8. Are accelerometers specified or can MDP be used?

BUILT FOR IT.™

CAT®

ARRA

JOB STUDY: MDP

Altoona, Iowa, USA

- Construction of freeway ramp near Altoona, Iowa, USA
- Glacial till placed in 20 cm (8 in) lifts
- CS74B (16 T) equipped with a padfoot shell kit and Cat Compaction Control with Machine Drive Power (MDP) and GNSS Mapping (RTK).
- Iowa Type A Specification requires 8 passes (about 1 pass per inch of fill)
- Quality Control included testing every 1,300 yd^3 (nuclear gauge, Standard Proctor – 95%)

JOB STUDY: MDP

Altoona, Iowa, USA

- Contractor and agency gained trust in MDP reading as work progressed
- Pass count requirement reduced from **8** to **2-3** to minimize wasted effort
- Number of QC tests reduced **75%**

- ***MDP reduced the time it took to complete the work by reducing total passes and testing***
- ***MDP saved costs by reducing fuel burn and costs associated with testing and delays***

JOB STUDY: MDP

How does reduced QC testing affect cost and time?

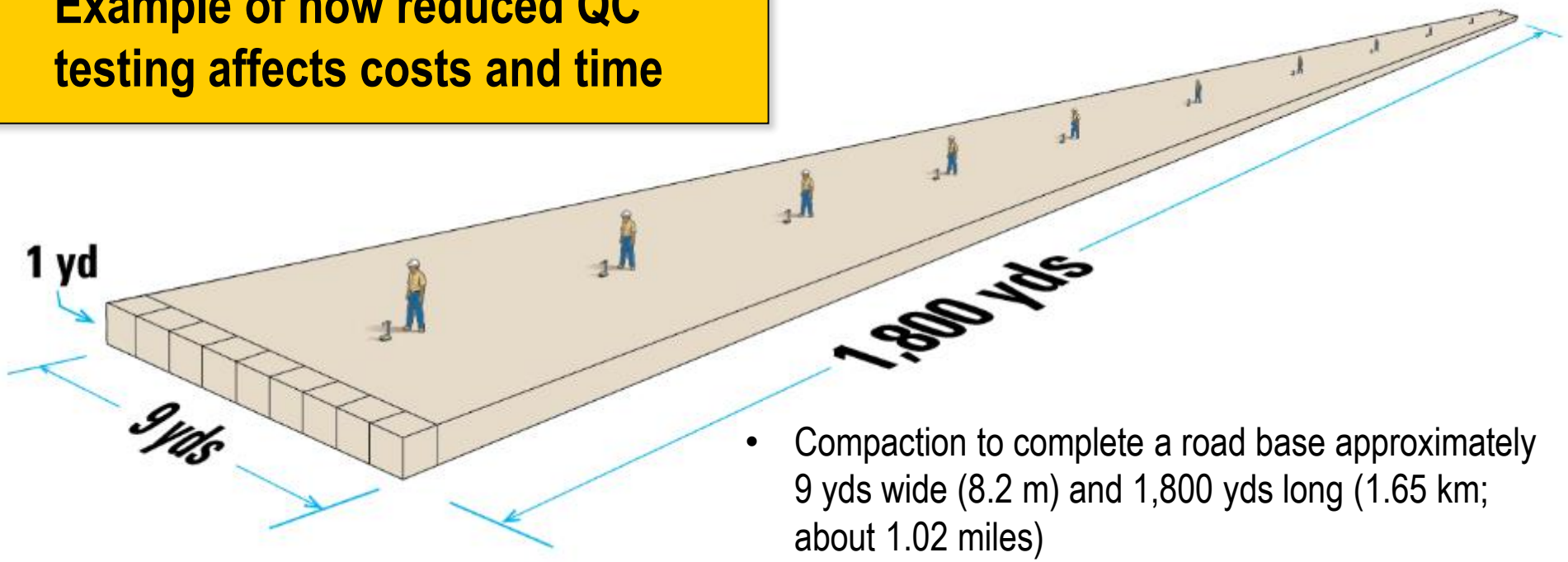
- Each test requires that a test procedure is performed at a particular place with specific people present
- Often, large tractors are necessary to scrape fluffed material to compacted level
- Production crew waits until procedure is complete

What are your costs per hour when your crew is idle?

JOB STUDY: MDP

Example of how reduced QC testing affects costs and time

Imagine a two lane road construction project…

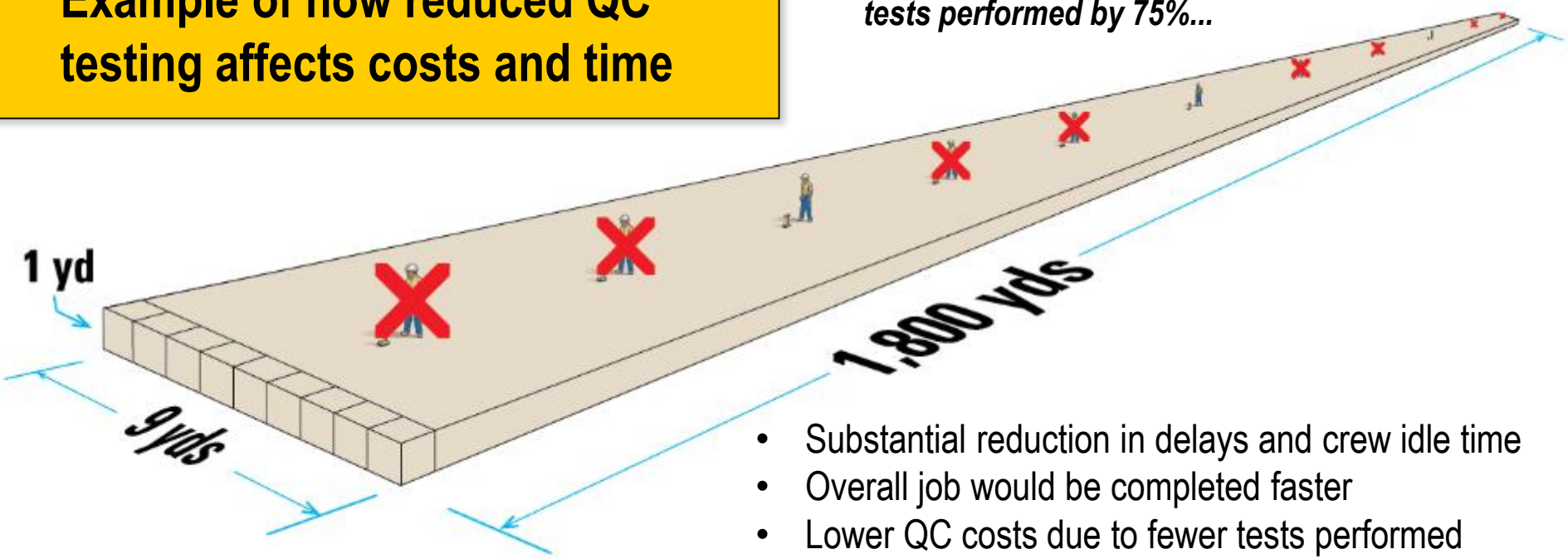


- Compaction to complete a road base approximately 9 yds wide (8.2 m) and 1,800 yds long (1.65 km; about 1.02 miles)
- QC test required every 1,500 yd^3
- Total tests required: 10.8 tests per 1,800 linear yards

JOB STUDY: MDP

Example of how reduced QC testing affects costs and time

Imagine you were able to reduce your tests performed by 75%...



- Substantial reduction in delays and crew idle time
- Overall job would be completed faster
- Lower QC costs due to fewer tests performed
- Better job site safety: less people, equipment on site

JOB STUDY: MDP

Triantafullia, Northern Greece

- Construction of clay core for rock fill dam in Triantafullia, Northern Greece
- Sandy clay placed in 20 cm (8 in) lifts, compacted to 15 cm (6 in)
- CS66B (12.3 T) equipped with a padfoot shell kit and Cat Compaction Control with Machine Drive Power (MDP)
- 12 passes at a rolling speed of 2 km/h required per lift
- Quality Control 98% Standard Proctor with no more than 5% of tests falling between 96% and 98%

JOB STUDY: MDP

Triantafullia, Northern Greece

- Contractor and agency gained trust in MDP reading as work progressed
- Pass count requirement reduced from **12** to **8** to minimize wasted effort
- Working speed increased from **2** km/h to **4.5** km/h

- ***MDP reduced the time to complete the work by reducing total passes and increasing the working speed***
- ***MDP saved costs by reducing fuel burn due to eliminating wasted effort***

JOB STUDY: MDP

Triantafullia, Northern Greece

How many passes were saved?

- **280** total lifts were required
- Average of **8.5** compaction “lanes” per lift
- **34** passes eliminated per lift on average
- **9,520** total passes eliminated

Imagine the fuel and time savings